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Project Summary

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Source Test and Evaluation Report: D. H. Mitchell Unit No. 11, Northern Indiana Public Service Co.

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A comprehensive multimedia emissions assessment was performed on NIPSCO's Dean H. Mitchell No. 11 boiler. This unit is equipped with an ESP for particulate control and a Wellman-Lord/Allied Chemical flue gas desulfurization (FGD) system. Level 1 and Level 2 procedures were used to characterize pollutant emissions in gaseous, liquid, and solid waste streams.

Flue gas analyses indicated SO_2 emissions of 266 ng/J after 89% removal by the FGD. Primary sulfate emissions of 20.8 ng/J comprised 5 mole percent of the total sulfur species emitted. Average emissions of NO_x (as NO_2) were 265 ng/J at the 70 percent boiler load maintained during the test period. Carbon monoxide emissions were estimated to be 16 ng/J, on the average, based on measurements at the air heater inlet. Particulate emissions (exclusive of H_2SO_4 aerosol) were 2.6 ng/J and 98 percent of the particles were smaller than 3 μm in diameter. H_2SO_4 aerosol emissions were 3.7-10.4 ng/J, or more, and were generally smaller than 0.5 μm in diameter. Total organic emissions ranged from 0.5 to 1.3 ng/J and consisted primarily of C_1-C_8 compounds. POMs were not detected at either the scrubber inlet or outlet. Concentrations of elements in the flue gas after scrubbing were below DMEGs and AMEGs in all cases. Emissions of NO_3^-, Cl^-, and F^- were 0.004, 0.25-0.34, and 0.033 ng/J, respectively. Emission concentrations of Cl^- and F^- were below their respective DMEGs. Flue gas pollutant concentrations were also determined at the air heater inlet and scrubber inlet.

Elemental concentrations in clarifier overflow, the only liquid waste discharged from the site, did not exceed health DMEGs although concentrations of Al, Ca, Cd, Fe, Ni, P, and Pb exceeded ecology DMEGs. However, Ca, Cd, Ni, and Pb are present in the process feedwater from Lake Michigan at concentrations similar to those measured in the clarifier overflow. Total organic concentrations in the liquid waste were 0.108-0.117 g/m^3 and consisted primarily of high molecular weight compounds (>C_{16}). Organic concentrations in the process feedwater from Lake Michigan were 0.235-0.242 g/m^3. No POMs were detected in the liquid waste. Individual liquid waste streams including the prescrubber slurry liquids, thiosulfate purge, and melt tank purge were also evaluated.

Fly ash, prescrubber solids, and ash pond sludge contained several elements at concentrations exceeding DMEGs. Elements of principal concern included Al, As, Fe, Ni, and P. Organic concentrations were approximately 4.7 mg/kg and consisted primarily of high molecular weight

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compounds (>C_{16}). POMs were not detected in the solid waste. Sodium salts in the thiosulfate and melt tank purge streams, soda ash, and product sulfur were also analyzed.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

A comprehensive multimedia emissions assessment was performed on the Northern Indiana Public Service Company's Dean H. Mitchell No. 11 boiler. A simplified schematic of Unit No. 11 is presented in Figure 1. This unit is a wall-fired, dry-bottom radiant boiler with a maximum steaming capacity of 103 kg/s and a corresponding turbo-generator output of 115 MW. Normal output ranges from 46 MW to 115 MW with an average load factor of 80% or 92 MW. The unit is fueled with a high volatile bituminous coal from the Captain Mines No. 6 seam. Typical fuel ash and sulfur contents are 9.5% and 3.2%, respectively. Average ash and sulfur contents during the test period were 12.5% and 3.5% (dry bases), respectively. Particulate emissions are controlled with a cold-end American Standard Co. electrostatic precipitator (ESP) and sulfur dioxide emissions are controlled with a Wellman-Lord/Allied Chemical flue gas desulfurization (FGD) unit. The FGD system represents the first application of Davy McKee's Wellman-Lord (W-L) process to a coal-fired boiler and the first combination of the W-L process with Allied Chemical's SO_2 reduction process. A schematic of the W-L SO_2 recovery system is presented in Figure 2.

The principal waste streams from this system are bottom and fly ash, prescrubber slurry from a venturi contactor, and flue gas. Bottom ash samples from the No. 11 boiler could not be obtained because the sluice system combines ash from all units at the Mitchell station. Solid and liquid wastes are discharged to a system of three primary ash storage ponds totaling 122,000 m^3 in capacity. Solid wastes are dewatered and hauled to off-site disposal areas. Supernatant liquids are processed through either of two 14,000 m^3 clarifying ponds and discharged into Lake Michigan.

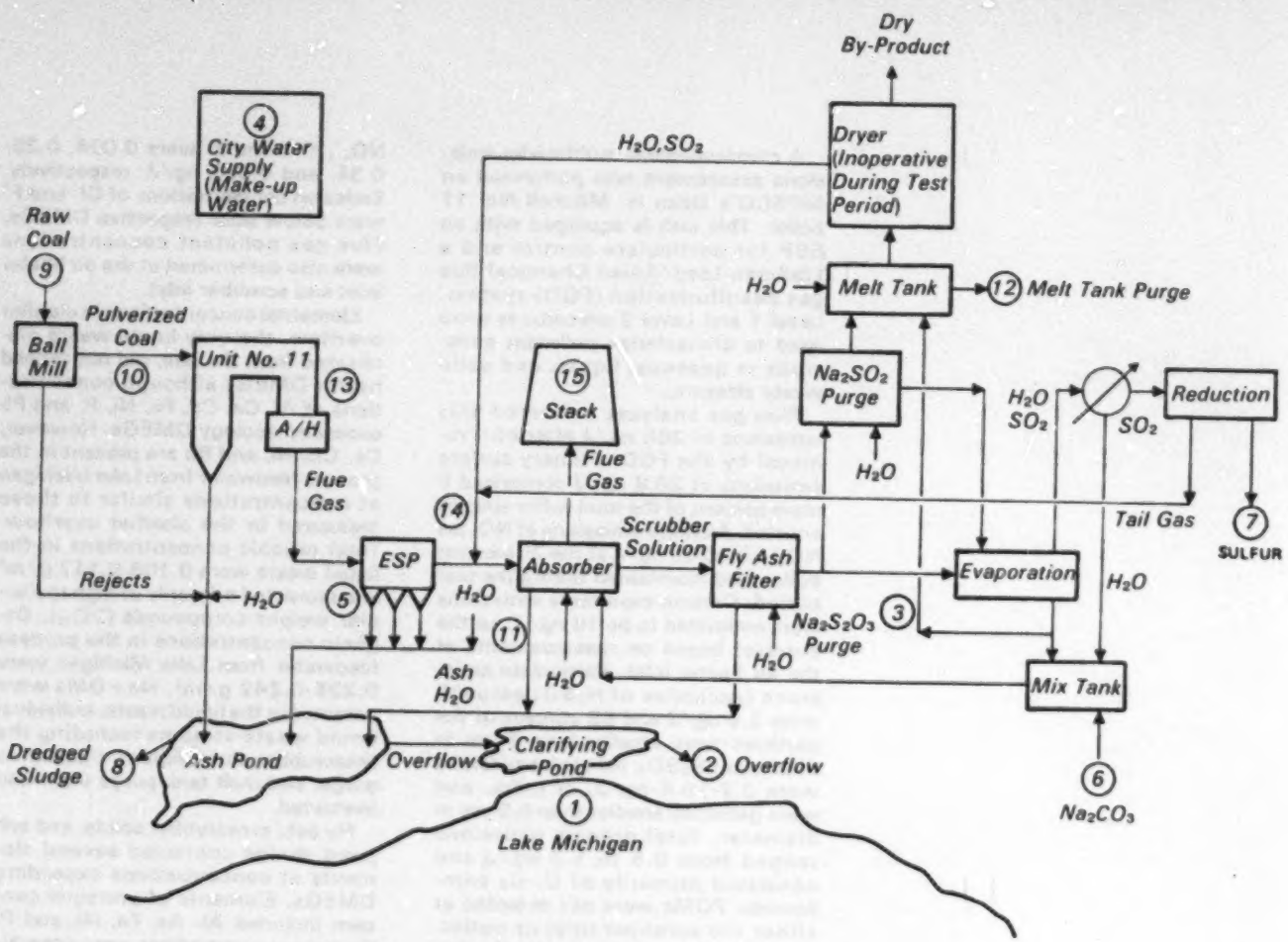

Figure 1. Schematic of Dean H. Mitchell No. 11 Unit.

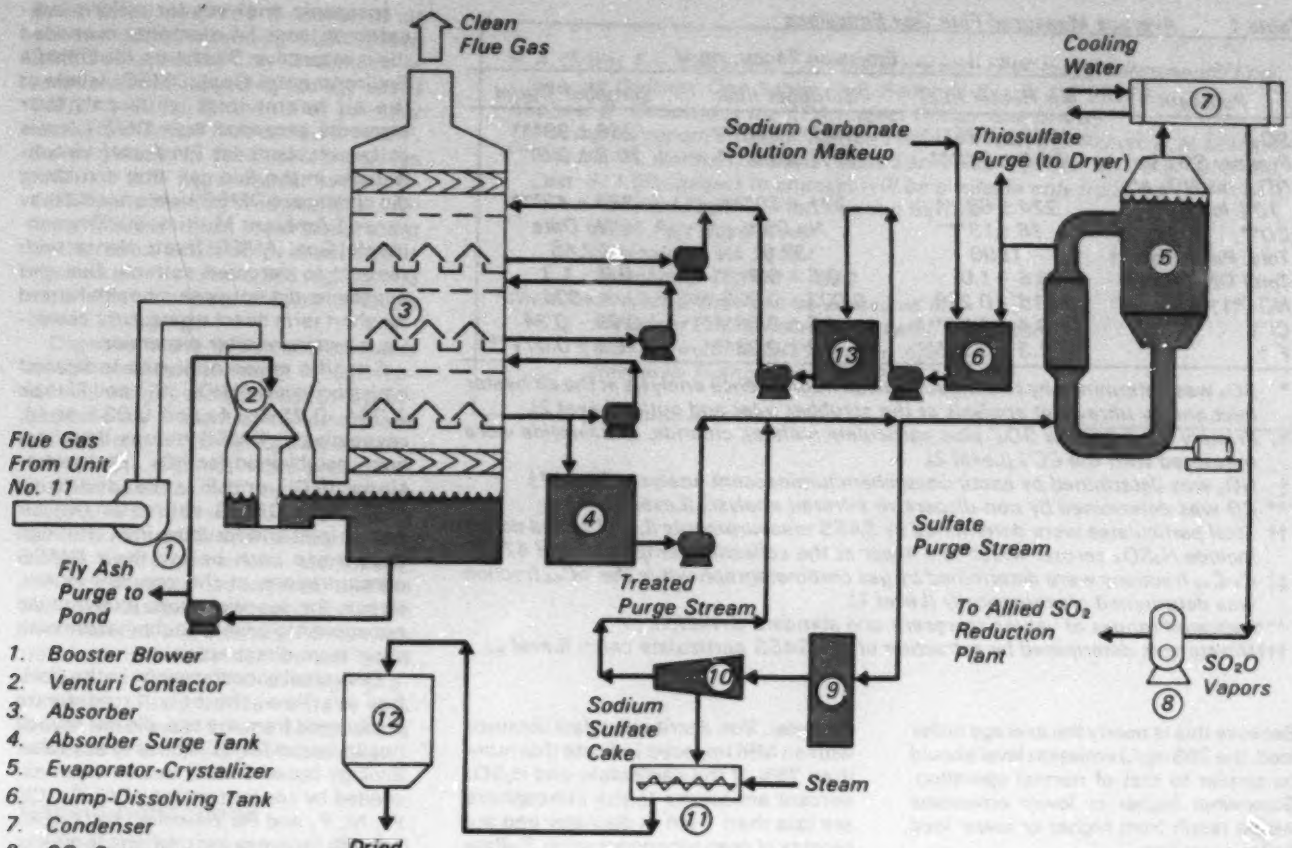

Figure 2. Schematic of the Wellman-Lord SO_2 recovery system.

Two additional streams were being discharged from the FGD system during the test period: 1) the melt tank liquor and 2) the thiosulfate purge. These streams would be dried to produce a solid by-product during normal operation; however, equipment problems necessitated the discharge of these streams into the ash pond during the entire test period.

Summary and Conclusions

Average measured flue gas emissions are summarized in Table 1. Emissions data indicated an SO_2 scrubbing efficiency of 89% based upon scrubber inlet and outlet data. Sulfur dioxide levels measured at the air heater inlet appeared to be erroneously low based upon feed coal sulfur concentrations; this can be partially attributed to instrument drift, although the cause is not entirely understood. Primary sulfate (SO_3 as $SO_4^=$ plus particulate sulfate) comprised 0.6% of the flue gas sulfur species at the scrubber inlet and 5% at the scrubber outlet. Primary sulfate at the scrubber inlet and outlet consisted of essentially equal mole fractions of SO_3 and particulate sulfate. However, data from the source assessment sampling system (SASS) indicate particulate sulfate levels of 2.2 and 0.6 ng/J at the scrubber inlet and outlet, respectively, compared to the 10 ng/J levels indicated by the controlled condensation system (CCS). These data may indicate that SO_3 was adsorbing on the particulate filter of the CCS, resulting in inordinately high measured particulate sulfate levels. Because of the large duct width and the proximity of the sampling ports to a right-angle bend at the economizer outlet, particulate stratification is probable at the air heater inlet. For this reason, measured primary sulfate levels at the air heater inlet are considered to be low.

Total oxides of nitrogen were determined during a period of 70% boiler load.

Table 1. Average Measured Flue Gas Emissions

Pollutant	Emission Factor, ng/J		
	Air Heater Inlet	Scrubber Inlet	Scrubber Outlet
SO_2*	1968 ± 145***	2482 ± 158***	266 ± 39***
Primary $SO_4^=$†	24.8 ± 3.0***	21.7 ± 5.6***	20.8 ± 2.9***
NO_x‡ (as NO_2 at 70% load)	224 ± 68***	271 ± 50***	263 ± 43***
CO**	16 ± 13***	No Data	No Data
Total Particulate††	1590	39.8	2.65
Total Organics‡‡	0.6 - 1.0	0.5 - 0.9	0.9 - 1.3
NO_3^-†††	0.215 - 0.219	0.003 - 0.006	0.004
Cl^-†	3.4 ± 0.56***	4.5 ± 0.89***	0.25 - 0.34
F^-†	1.3 ± 0.34***	1.2 ± 0.38***	0.033 ± 0.011***

* SO_2 was determined by continuous pulsed fluorescence analysis at the air heater inlet and by ultraviolet analysis at the scrubber inlet and outlet (Level 2).

† Primary $SO_4^=$ (SO_3 as $SO_4^=$ plus particulate sulfate), chloride, and fluoride were measured with the CCS (Level 2).

‡ NO_x was determined by continuous chemiluminescent analysis (Level 1).

** CO was determined by non-dispersive infrared analysis (Level 2).

†† Total particulates were determined by SASS measurements (Level 1) and do not include H_2SO_4 aerosol which is a vapor at the collection temperature of 477 K.

‡‡ C_1-C_{16} fractions were determined by gas chromatograph while the $>C_{16}$ fraction was determined gravimetrically (Level 1).

***Indicated ranges of values represent one standard deviation.

†††Nitrate was determined by extraction of the SASS particulate catch (Level 2).

Because this is nearly the average boiler load, the 265 ng/J emission level should be similar to that of normal operation. Somewhat higher or lower emissions would result from higher or lower load boiler operation.

Carbon monoxide was monitored only at the air heater inlet. While leakage across the air heater may reduce CO levels slightly, neither the ESP nor the scrubber affect flue gas CO levels. Hence, the 16 ng/J CO level measured at the air heater inlet should accurately reflect actual emission levels.

Total particulate data indicate an ESP removal efficiency of 97.5% and a scrubber efficiency of 93.3%; however, the actual ESP removal efficiency probably exceeds 97.5% since particulate stratification apparently resulted in a low particulate catch at the air heater inlet. Particulate at the air heater inlet and scrubber inlet consisted primarily of particles larger than 3μm. At the air heater inlet, 44% of the particulate were larger than 10μm, 42% were 3-10μm, 13% were 1-3μm, and 1% were smaller than 1μm. At the scrubber inlet, 25% of the particulate were larger than 10μm, 39% were 3-10μm, 20% were 1-3μm, and 17% were smaller than 1μm. Only 2% of the particulate emissions to the atmosphere were larger than 3 μm, while 98% were less than 3μm in diameter. Size distribution data obtained with an MRI impactor indicate that more than 76% of the particulate and H_2SO_4 aerosol emissions to the atmosphere are less than 1 μm in diameter and are capable of deep lung penetration. Sulfate analyses of the impactor plates indicated H_2SO_4 aerosol emissions ranging from 3.7 to 10.4 ng/J with a diameter generally less than 0.5 μm.

Total organic emissions ranged from 0.5 to 1.3 ng/J and consisted primarily of C_1-C_8 organics. The light hydrocarbons were not removed by flue gas processing although decreases in higher molecular weight organics were observed across the ESP and the scrubber. Flue gas processing removed 87% of the C_7-C_{16} organics and 82% of the $>C_{16}$ organics. Higher molecular weight organics were found to consist of aromatics, unsaturated hydrocarbons, and either esters or phenols. POMs were not detected at the scrubber inlet or outlet. At the air heater inlet, phenanthrene was detected at 0.7 $\mu g/m^3$ (0.2 pg/J), and fluoranthene and dibenzanthracene were detected at concentrations below 0.6 $\mu g/m^3$ (0.2 pg/J). With the possible exception of dibenzanthracene (which could be dibenz(a,h)anthracene), measured concentrations of these compounds do not appear to pose a hazard to human health.

Inorganic analyses for cations indicated at least 14 elements exceeded their respective Discharge Multimedia Environmental Goal (DMEG) levels at the air heater inlet while only four elements exceeded their DMEG levels at the scrubber inlet. Elemental concentrations in the flue gas after scrubbing did not exceed DMEG levels nor did they exceed Ambient Multimedia Environmental Goal (AMEG) levels. Hence, with respect to detected cations, flue gas emissions did not pose a health hazard for short term direct exposure or continuous exposure after dispersion.

Specific anion analyses indicated emission levels of NO_3^-, Cl^-, and F^- to be 0.004, 0.25-0.34, and 0.033 ng/J, respectively. DMEG values have not been established for NO_3^-. Concentrations of Cl^- and F^- exceeded their respective DMEG values at the air heater inlet and scrubber inlet although they were both below their DMEG concentrations at the scrubber outlet. Hence, the specific anions analyzed did not appear to pose a health hazard with short term direct exposure.

Elemental concentrations in the clarifier overflow, the only liquid waste discharged from the site, did not exceed health-based DMEG values in any case. Ecology-based DMEG values were exceeded by concentrations of Al, Ca, Cd, Fe, Ni, P, and Pb. However, Ca, Cd, Ni, and Pb are present in the process feedwater from Lake Michigan at concentrations similar to those measured in the clarifier overflow. Elemental concentrations in the prescrubber slurry liquids exceeded health-based DMEG values for B, Cr, and Fe, and exceeded ecology-based DMEG values for numerous elements (notably Al, Cd, Fe, Ni, and P). Concentrations of numerous elements in the thiosulfate purge liquids and melt tank liquor exceeded DMEG values.

Organics in the liquid waste streams consisted primarily of $>C_{16}$ compounds. C_7- C_{16} organic concentrations in liquid wastes were generally below the detection limit of 0.001 g/m^3. Total organic concentrations in the prescrubber slurry liquids and clarifier overflow were 0.351-0.361 g/m^3 and 0.108-0.117 g/m^3, respectively. Organics were present in the process feedwater from Lake Michigan at a concentration of 0.235-0.242 g/m^3. No POMs were detected in liquid wastes or process water streams.

Solid waste streams (fly ash, prescrubber solids and ash pond sludge)

each contained 4 to 6 elements at concentrations exceeding health-based DMEG values and 11 or 12 elements at concentrations exceeding ecology-based DMEG values. Elements of primary concern included Al, As, Fe, Ni, and P. Solids present in the thiosulfate purge and melt tank liquor appear to be relatively pure Na_2SO_3 and $NaHSO_3$, respectively. Elemental impurities present in the soda ash and product sulfur streams did not exceed 265 mg/kg, and most elements were present at levels below 10 mg/kg.

Organics in the fly ash and ash pond sludge consisted primarily of high molecular weight compounds; C_7-C_{16} organics were present at concentrations of 0.345 and 0.245 mg/kg, respectively, while $>C_{16}$ organics were present at concentrations of 4.42 and 4.48 mg/kg, respectively. Solid wastes were found to contain saturated hydrocarbons, aromatics, esters, and ethers. Additionally, the fly ash contained ketones, and the ash pond sludge contained unsaturated hydrocarbons and alcohols. POMs were not detected in fly ash or ash pond sludge samples. The average prescrubber slurry solids content was 0.47% and insufficient solids were collected to enable organic analyses.

Recommendations

This test effort has provided detailed characterization data for the NIPSCO Dean H. Mitchell No. 11 boiler system. However, limited supplemental particulate and sulfate data would be desirable. Additional MRI impactor size distribution data are required to more thoroughly characterize particulate at the scrubber inlet. Also, additional CCS data at the scrubber inlet and outlet would serve to clarify existing data regarding the SO_3 and particulate $SO_4^=$ loadings.

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***Michael C. Osborne** is the EPA Project Officer (see below).*
The complete report, entitled "Source Test and Evaluation Report: D. H. Mitchell Unit No. 11, Northern Indiana Public Service Co.," (Order No. PB 81-218 489; Cost: $11.00, subject to change) will be available only from:
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